WARM AND COLD FORGING

PRECISION FORGING
COLD HEADING
COLD EXTRUSION
Precision forging

Main characteristics:

• Closed die forging
• Temperature is below the hot range, it is „warm” forging ($T \sim 0.5 \times T_m$ °K)
• Close tolerances, acceptable surface finish – „near net shaping process”
• Good material yield
• Good mechanical properties
Economic considerations

• Precision forging is more costly than conventional forging, …but!
• Savings in material and machining costs are significant
• Forming complex shapes is possible
• Precision forging represents a higher value product than a conventional forging (higher added value)
Temperature of forging

Low alloy steels:

<table>
<thead>
<tr>
<th>Type</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold forging</td>
<td>&lt; 250 °C</td>
</tr>
<tr>
<td>Warm forging</td>
<td>540 ... 815 °C</td>
</tr>
<tr>
<td>Hot forging</td>
<td>950 ... 1150 °C</td>
</tr>
</tbody>
</table>

Controlled cooling may be necessary after forging to avoid distortion and to control the microstructure of the workpiece.
Tooling (1)

• Dimensions
  – Allowances (thermal contraction, machining)
  – Draft angles, no sharp corners – good material flow

• Workability
  – High deformation levels – needs good formability
  – Try to avoid cracking!
Tooling (2)

• Precision:
  – Tolerance bands of tool: 10…30% of the workpiece
  – High-precision machining (EDM)
  – Rigid alignment
  – Preform considerations (volume, weighting, appropriate shape)

• Conditions: good lubrication, remove contaminants, good control of billet and tool temperature
Forging equipment

• Billet separation: shearing or sawing
• Heating:
  – Furnace – oxide formation
  – Induction heating
  – Resistance heating
• Presses:
  – Hammers
  – Crank presses
  – Hydraulic presses
Comparison of forgings
Cold forging

• Processes:
  – Upsetting
  – Cold forging of components

• Effect of cold working on material properties
  – the ductility of the material drops, strengths and hardness increases (because of higher dislocation density - strain hardening)
  – the microstructure changes, crystals (grains) become elongated in the direction of major deformation
Cold heading

- To upset the metal in a portion of wire or rod blank
- The cross-sectional area of the initial material is increased as the height of the workpiece is decreased
- variants:
  - Free (head formed between flat punch and die)
  - Closed (head formed in punch and die)
Limits of deformation

Material dependent:

\[ \frac{L}{d} \leq 2.3 \]

\[ \frac{D}{d} \Rightarrow 2\ldots2.7 \]

Material independent:

\[ \frac{D}{k} \Rightarrow 2\ldots3 \]
Calculation of force

\[ F = k_f A \left(1 + \frac{2\mu}{3h} R\right) \]

Where:

- \( k_f \) flow stress
- \( A \) cross-sectional area
- \( R \) radius of head
- \( h \) height of head
- \( \mu \) coefficient of friction
Two-stroke upsetting

• If $L/d > 2.3$ then two operations are needed:
  – Preforming
  – Finish heading

• Preforming head: conic-cylindrical

• Finish: closed heading punch
Example: screw

head
shearing
heading
reduction
shearing
Example: screws and bolts
Example: heading

• Closed-die cold heading
• Die can be opened for feeding and removing the workpiece
Head shearing
Cold extrusion of parts

- Principle: a punch applies pressure to the preform or billet, causing the work metal to flow in the required direction
- Process variants:
  - Direct – indirect or forward – backward
  - Extrusion of rod, can and hollow part
  - Single or combined operations
Forward extrusion of rod
Backward extrusion of can
Combined: forward and backward extrusion of can
Combined: forward extrusion of rod, backward extrusion of can.
Cold extrusions

- Forward extrusion of rod
- Back extrusion of can
- Forward extrusion of can
Extrusion pressure and force

- Extrusion pressure:

\[ p = \frac{k_{fm} \varphi}{\eta} \]

where:
- \( k_{fm} \) mean flow stress
- \( \varphi \) logarithmic strain: \( \ln(A_0/A_1) \)
- \( \eta \) coefficient of extrusion (0.4...0.7)
Extrusion pressure and force

• Punch load (force)
  \[ F = \rho A \]

• Work (energy)
  \[ W = c F \Delta h \]
  (c=0,6…0,8)
  
• where:
  - \( A \) cross sectional area
  - \( \Delta h \) punch travel
Materials and lubrication

• Good formability:
  mild steel, copper, aluminium

• Medium formability:
  low alloy steels, Zn

• Preparation for cold forging:
  – Surface treatment
  – Lubrication
  – Forging
Equipment

• **Machines:**
  – Crank presses
  – Knuckle-joint presses
  – Hydraulic presses
  – Special purpose cold forging and heading machines

• **Requirements:**
  – Sufficient flywheel energy and load capacity
  – Rigid frame
Presses

crank press  knuckle-joint press
Automated press

<table>
<thead>
<tr>
<th>Feeding, shearing</th>
<th>Preforming of head</th>
<th>Cold heading</th>
<th>Coining and sizing</th>
</tr>
</thead>
</table>
Cold Forging Machines
Cold forged parts
Example: multiple-step forging

Forward extrusion of rod, back extrusion of can and rod

Forward extrusion of hollow part

Radial extrusion
Example: multiple-step forging

<table>
<thead>
<tr>
<th>Billet</th>
<th>Back extrusion of can</th>
<th>Piercing</th>
<th>Radial extrusion</th>
</tr>
</thead>
</table>
Example: production of nut
Comparison of material yield and energy consumption

<table>
<thead>
<tr>
<th>Process</th>
<th>Material yield, %</th>
<th>Energy, $10^6$ J/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold forging</td>
<td>85</td>
<td>41</td>
</tr>
<tr>
<td>Warm forging</td>
<td>85</td>
<td>41</td>
</tr>
<tr>
<td>Hot forging</td>
<td>75…80</td>
<td>46…49</td>
</tr>
<tr>
<td>Cutting</td>
<td>40…50</td>
<td>66…82</td>
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